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G2F FCW F23E F28C F28W

(56) Documents Cited
EP 1055946 A2
WO 99/59012 A1
JP 090211244 A
US 5689597 A
EP 0651267 A1
WO 98/39679 A1
US 6047096 A
US 4991926 A

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INT CL[7] G02B
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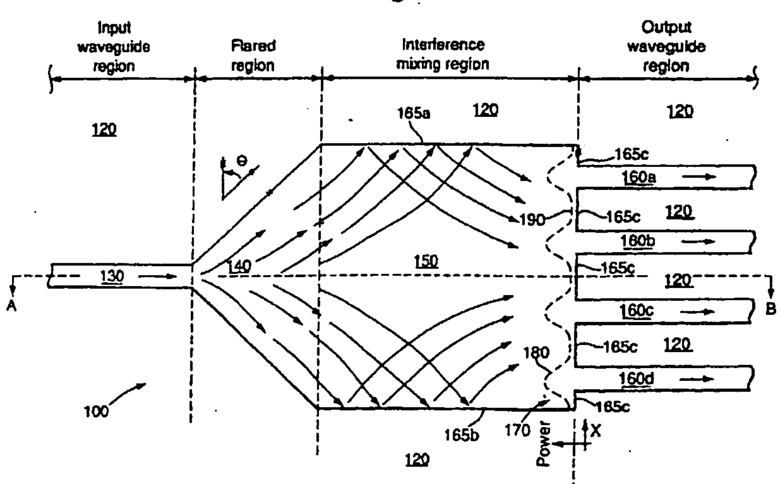
(54) Abstract Title
Flared optical waveguide coupler

(57) A flared optical coupler (100) comprising an input/output waveguide (130), an interference mixing waveguide region (150) and a plurality of output/input waveguides (160), the coupler (100) operable to couple radiation from/to the input/output waveguide (130) into the mixing region (150) for generating one or more radiation power maxima (180) therein, said one or more maxima for coupling radiation into/from one or more of the output/input waveguides (160), characterised in that the coupler (100) includes a flared waveguide region (140) for coupling between the input/output waveguide (130) and the mixing region (150).

An electro-optical modulator (400, Fig 5) for selectively diverting input radiation received at the modulator to a plurality of output waveguides (480, Fig 5), the modulator including:

(a) a coupler (430, 440, Fig 5) according to the invention for coupling the input radiation into a plurality of intermediate waveguide paths (450, Fig 5);
(b) modulating means (460, Fig 5) for applying relative phase modulation to radiation propagating along the intermediate waveguides; and
(c) output mixing means (470, Fig 5) for mixing radiation output from the intermediate waveguides and thereby diverting radiation to one or more of the output waveguides in response to one or more modulating signals (M_1, M_2) applied to the modulating means.

Fig.3.



At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

This print takes account of replacement documents submitted after the date of filing to enable the application to comply with the formal requirements of the Patents Rules 1995

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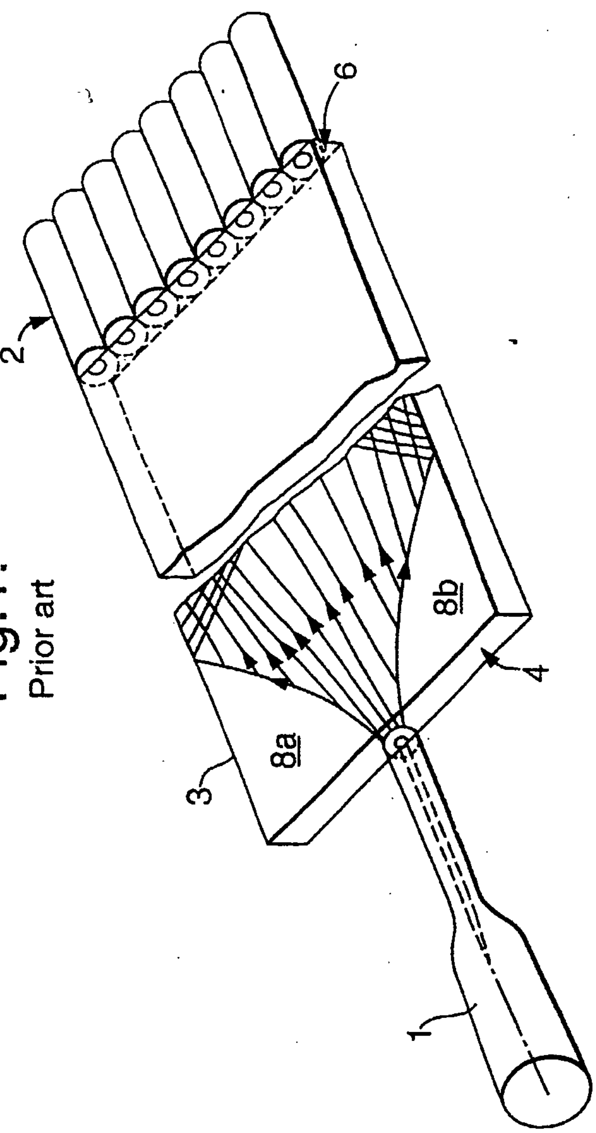


Fig.1.
Prior art

Fig.2.

Prior art

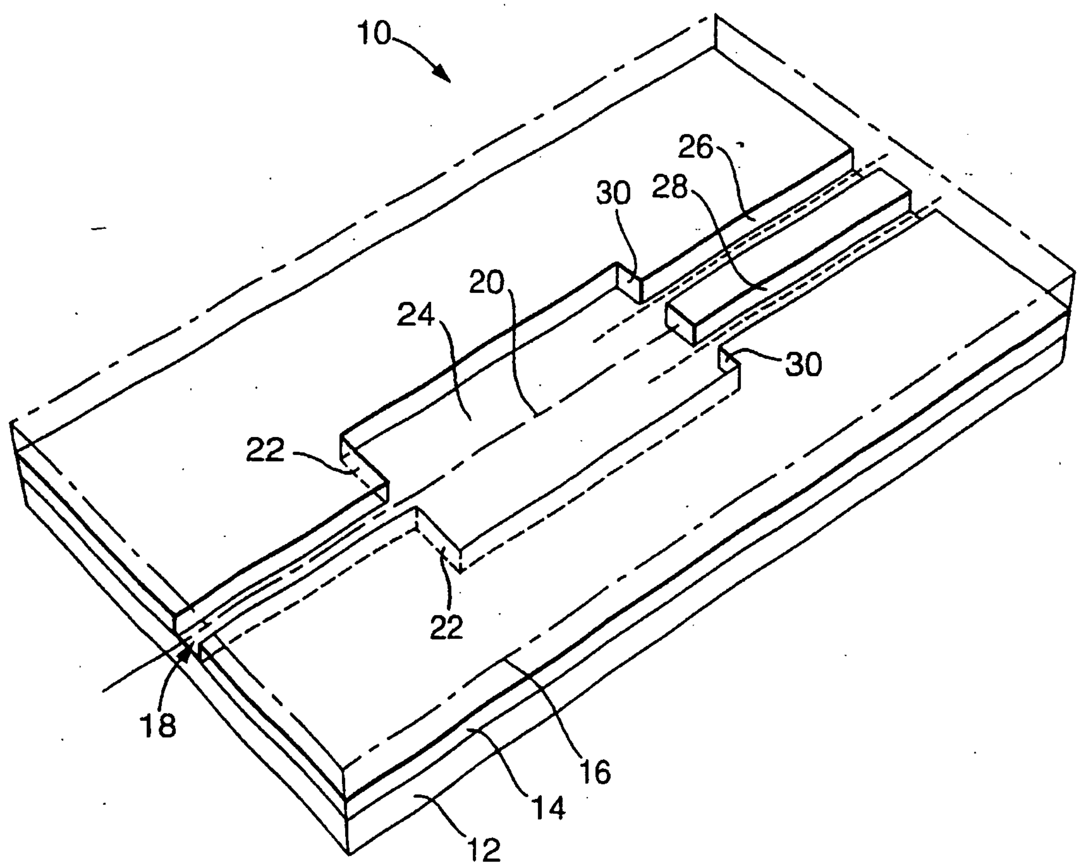
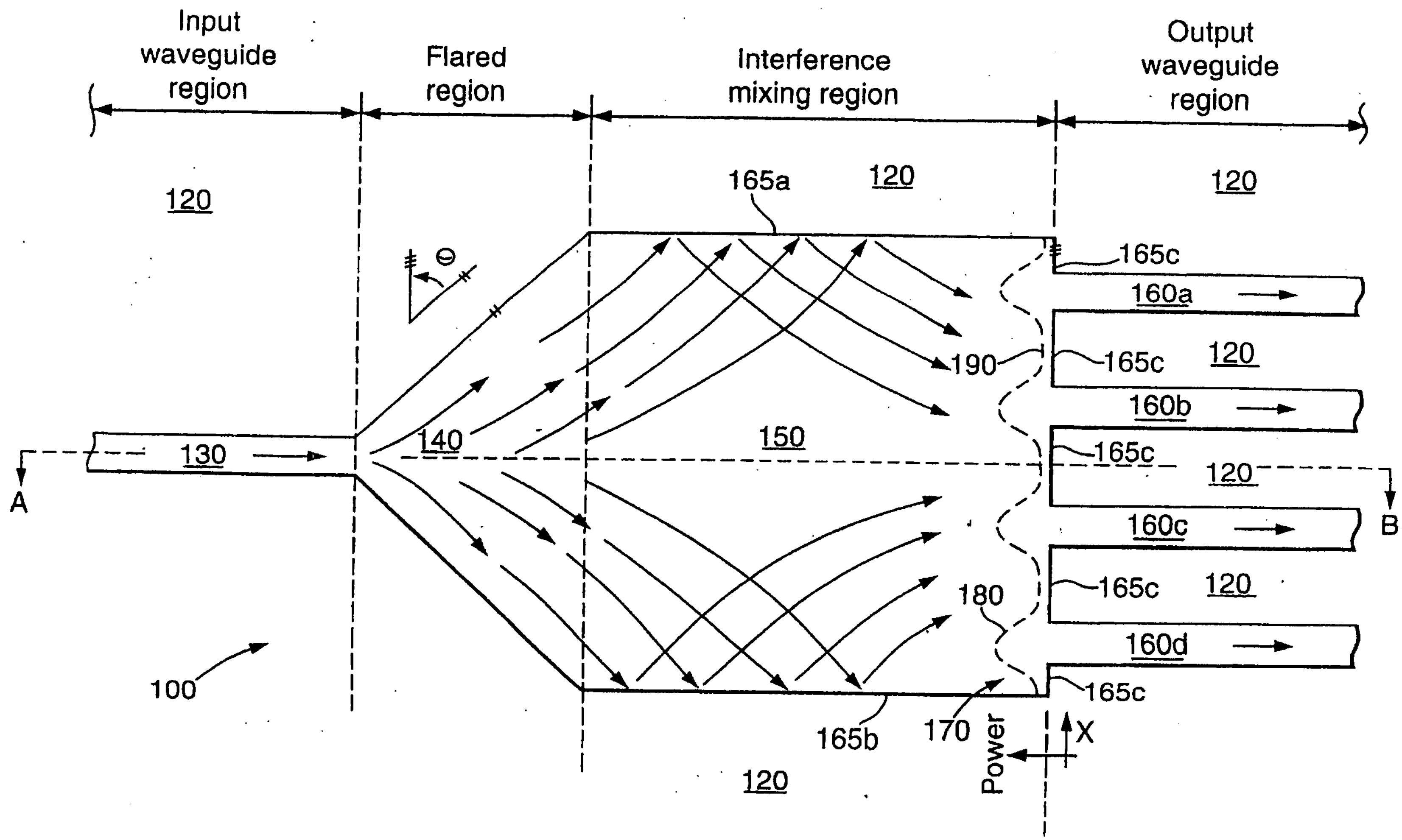


Fig.3.



Input waveguide region
Flared region
Interference mixing region
Output waveguide region
120
120
165a
120
120
165c
160a
165c
120
160b
165c
120
160c
165c
120
160d
165c
130
140
150
190
180
170
165b
120
Power
X
A
B
100
Θ

Fig.4.

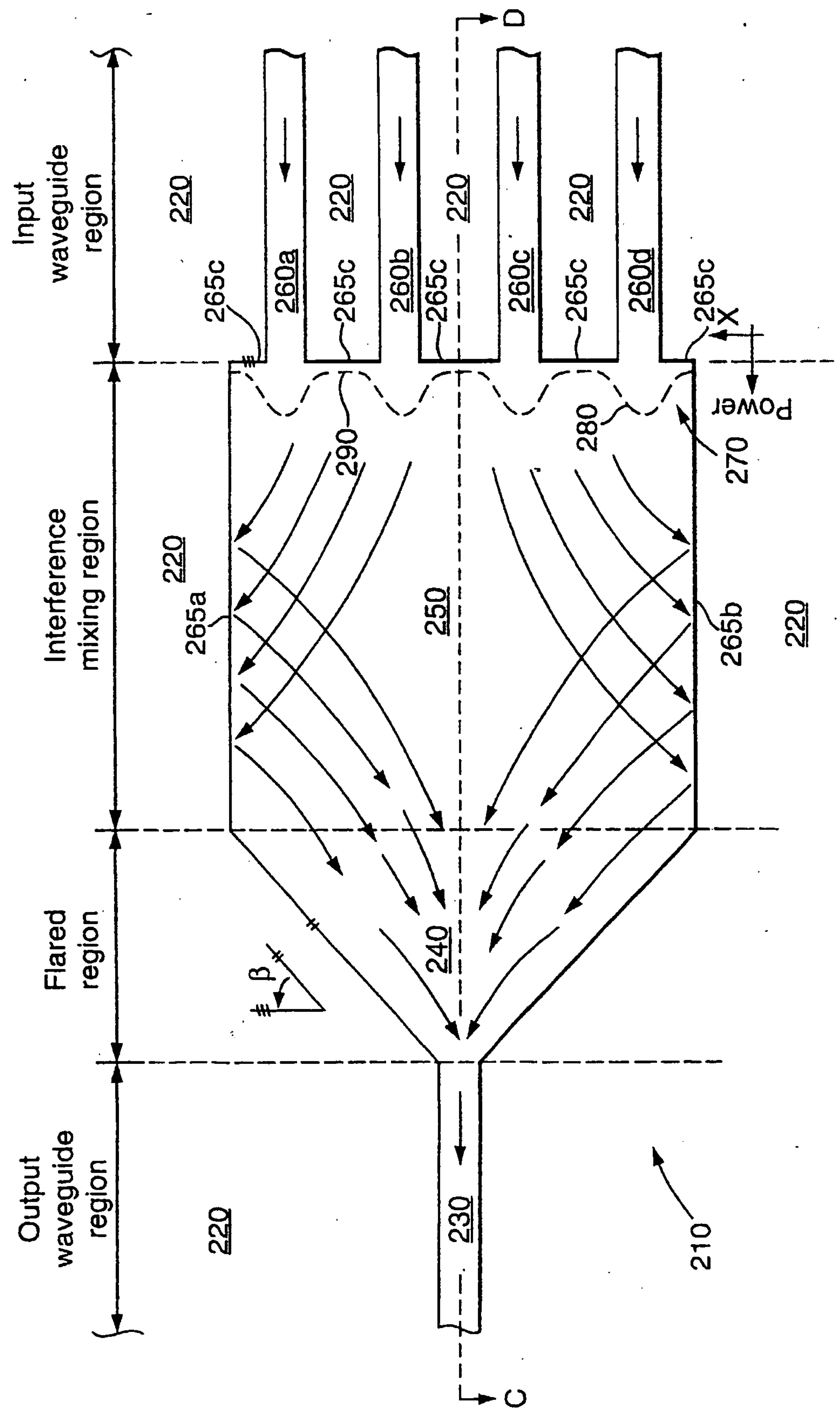
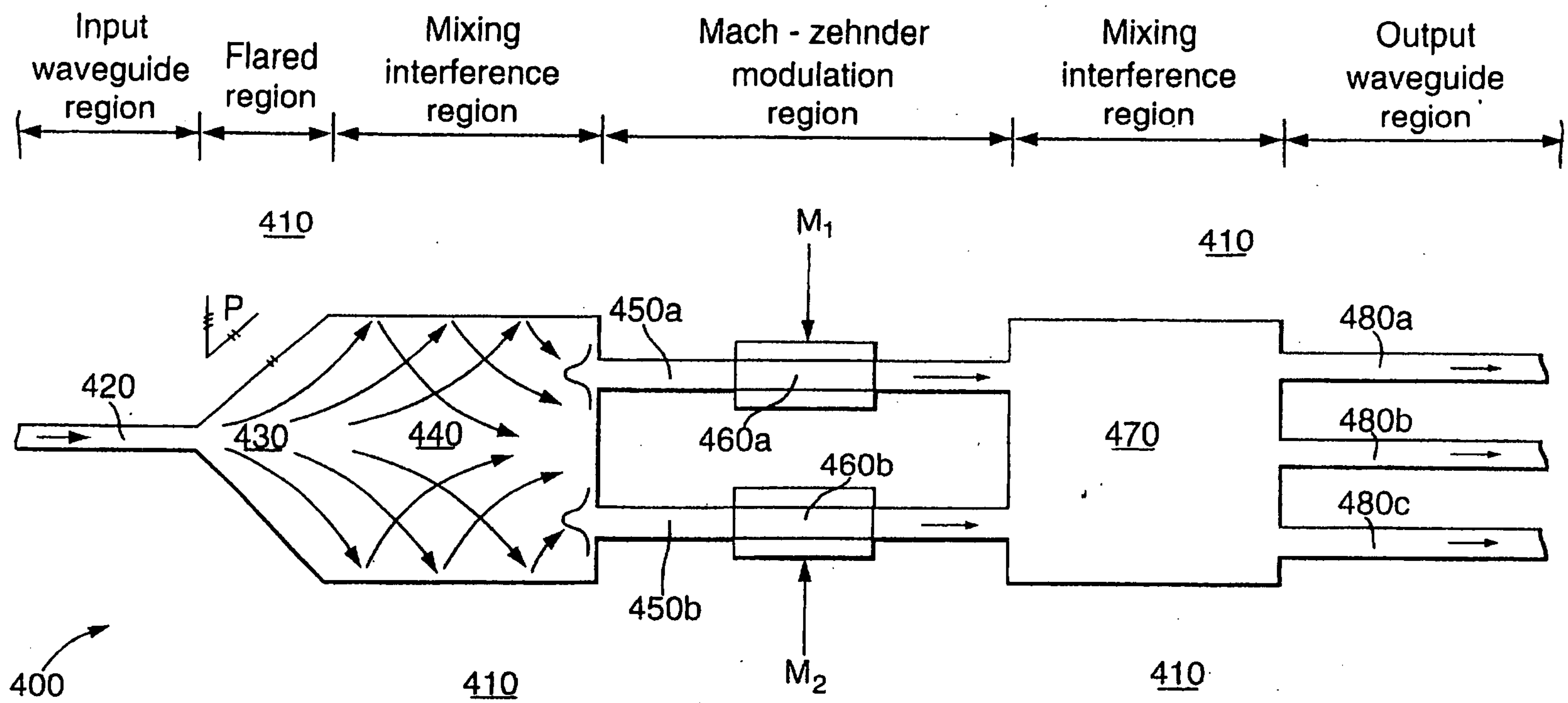

Input waveguide region
Interference mixing region
Flared region
Output waveguide region
220
260a
260b
260c
260d
265c
265a
265b
250
240
230
270
280
290
210
X
Power
β
D
C

Fig.5.



Input waveguide region
Flared region
Mixing interference region
Mach - zehnder modulation region
Mixing interference region
Output waveguide region
410
M1
410
P
450a
480a
420
430
440
460a
460b
470
480b
480c
450b
400
410
M2
410

FLARED OPTICAL COUPLER

The present invention relates to a flared optical coupler, in particular, but not exclusively, to a flared optical coupler implemented using rib waveguide technology.

Optical couplers are well known in the art.

For example, a 1xN single mode optical waveguide coupler is described in a United States patent no. US 4 950 045. The single mode coupler comprises a single input optical fibre waveguide, a slab-like mixer waveguide and a plurality of output optical fibre waveguides. The input waveguide is substantially centrally positioned with regard to a first end face of the slab. Moreover, the output waveguides are positioned in a row at a second end face of the slab, the second face opposite to a parallel to the first face. The slab-like waveguide is of rectangular shape in plan view and is substantially of uniform thickness.

In operation, fundamental mode radiation propagating along the input waveguide is injected into the mixer waveguide wherein it propagates and interferes to create radiation interference maxima at entrance pupils to the output waveguides. The radiation maxima couple relatively efficiently into the output waveguides and corresponding output radiation propagates away from the mixer waveguide along the output waveguides.

Another example of a known optical device coupler is described in a European patent no. EP 0 563 084 B1. The device coupler is implemented in hollow waveguide technology but comprises similar features to the aforementioned single mode optical coupler, namely the device coupler comprises an input waveguide centrally aligned and coupled to a first end of a hollow mixing region, and a plurality of output waveguides coupled to a second end of the mixing region, the second end opposite to the first end.

In operation, fundamental mode radiation propagating along the input waveguide is injected into the mixing region wherein it propagates and interferes to create radiation interference maxima at entrance pupils to the output waveguides. The radiation maxima couple relatively efficiently into the output waveguides and corresponding output radiation propagates away from the mixing region along the output waveguides.

The single mode optical coupler and the device coupler operate in an identical manner. The interference can either be considered as mode coupling within the mixing region and mixer waveguide as presented in the European patent, or considered as interference fringes of the fundamental mode radiation propagating within the mixing region and mixer waveguide as presented in the US patent. Both representations are essentially describing the same phenomenon, despite the different forms of waveguide being employed. Moreover, the US patent US 4 950 045 has an issue date earlier than the priority date of the European patent EP 0 563 084 B1. Furthermore, numerous other documents regarding the design of multi-mode couplers were published before the priority date of the European patent.

The inventor has appreciated that the performance of known optical couplers, for example the aforementioned single mode waveguide coupler and device coupler, can be further enhanced. The inventor has devised a flared region for inclusion between the input waveguides and the mixing region or mixer waveguide, the flared region improving performance achievable from the known couplers.

Thus, according to a first aspect of the invention, there is provided a flared optical coupler comprising an input waveguide, an interference mixing waveguide region and a plurality of output waveguides, the coupler operable to couple radiation from the input waveguide into the mixing region for generating one or more radiation power maxima therein, said one or more maxima for coupling radiation into one or more of the output waveguides, characterised in that the coupler includes a flared waveguide region for coupling between the input waveguide and the mixing region.

The invention provides the advantage that the flared region is capable of one or more of:

(a) functioning as a spatial filter to control higher-order mode artefacts present within the coupler; and

(b) assisting to more precisely and reliably define where the radiation power maxima occur.

Preferably, the flared region has a first aperture coupled to the input waveguide and a second aperture coupled to the mixing region, the first aperture being relatively narrower in width compared to the second aperture. Such widths for the first and second apertures provide a more satisfactory waveguide impedance match from the input waveguide to the mixing region.

Conveniently, the first aperture is of substantially similar lateral width as the input waveguide and the second aperture is of substantially similar lateral width as the mixing region.

Beneficially, peripheral radiation restraining walls of the flared region are substantially linearly flared.

Preferably, peripheral radiation restraining walls of the flared region are at an angle in a range of 30° to 60° relative to an end radiation restraining wall of the mixing region where the output waveguides join thereonto. Such a range of angles provides for enhanced operation of the coupler compared to prior art.

Preferably, the flared region, the input waveguide and the plurality of output waveguides are implemented in rib-waveguide technology. Use of rib-waveguide technology allows for coupler miniaturisation.

Advantageously, the rib-waveguide technology is based on a III-V semiconductor material system. Use of such a material system enables the coupler to be incorporated into active electro-optical subsystems, for example electro-optical modulators.

In a second aspect of the invention, there is provided a flared optical coupler comprising a plurality of input waveguides, an interference mixing waveguide region and an output waveguide, the coupler operable to couple radiation from one or more of the input waveguides into the mixing region for generating one or more radiation power maxima therein, said one or more maxima for coupling radiation into the output waveguide, characterised in that the coupler includes a flared waveguide region for coupling between the mixing region and the output waveguide.

Preferably, the flared region has a first aperture coupled to the output waveguide and a second aperture coupled to the mixing region, the first aperture being relative narrower in width compared to the second aperture.

Advantageously, the first aperture is of substantially similar lateral width as the output waveguide and the second aperture is of substantially similar lateral width as the mixing region.

Preferably, peripheral radiation restraining walls of the flared region are substantially linearly flared.

Beneficially, peripheral radiation restraining walls of the flared region are at an angle in a range of 30° to 60° relative to an end radiation restraining wall of the mixing region where the input waveguides join thereonto.

Preferably, in order to assist miniaturisation, the flared region, the output waveguide and the plurality of input waveguides are implemented in rib-waveguide technology.

Conveniently, the rib-waveguide technology is based on a III-V semiconductor material system. This material system enables the coupler to be incorporated into active electro-optical subsystems.

In a third aspect, the invention provides an electro-optical modulator for selectively diverting input radiation received at the modulator to a plurality of output waveguides, the modulator including:

(a) a coupler according to the first aspect of the invention for coupling the input radiation into a plurality of intermediate waveguide paths;
(b) modulating means for applying relative phase modulation to radiation propagating along the intermediate waveguides; and
(c) output mixing means for mixing radiation output from the intermediate waveguides and thereby diverting radiation to one or more of the output waveguides in response to one or more modulating signals applied to the modulating means.

Conveniently, to assist with miniaturisation, the modulator is implemented in rib-waveguide technology.

Preferably, the modulator is implemented in a III-V semiconductor material system. Indeed, advantageously, the modulating means is operable to exploit the Pockels effect for applying relative phase modulation to radiation propagating along the intermediate waveguides.

Embodiments of the invention will now be described, by way of example only, with reference to the following diagrams in which:

Figure 1 is a schematic diagram of a prior art 1xN single mode optical waveguide coupler as described in a United States patent no. US 4 950 045;

Figure 2 is a schematic diagram of a known optical device coupler as described in a European patent no. EP 0 563 084 B1;

Figure 3 is an illustration of a flared optical coupler according to the invention arranged to function as a 1 to 4 way coupler;

Figure 4 is an illustration of a flared optical coupler according to the invention arranged to function as a 4 to 1 way coupler; and

Figure 5 is a schematic diagram of a Mach-Zehnder modulator incorporating a flared optical coupler according to the invention.

Referring now to Figure 1, there is shown a schematic diagram of a prior art 1xN single mode optical waveguide coupler as described in a United States patent no. US 4 950 045. The single mode coupler comprises a single input optical fibre waveguide 1, a slab-like mixer waveguide 3 and a plurality of output optical fibre waveguides indicated by 2. The input waveguide 1 is substantially centrally positioned with regard to a first end face 4 of the slab waveguide 3. Moreover, the output waveguides 2 are positioned in a row at a second end face 6 of the slab waveguide 3, the second face 6 opposite to and parallel to the first face 4. The slab-like waveguide 3 is of rectangular shape in plan view and is substantially of uniform thickness.

In operation, fundamental mode radiation propagating along the input waveguide 1 is injected into the mixer waveguide 3 wherein it propagates and interferes to create radiation interference maxima at entrance pupils to the output waveguides 2. The radiation maxima couple relatively efficiently into the output waveguides 2 and corresponding output radiation propagates away from the mixer waveguide 3 along the output waveguides 2.

The inventor has appreciated that lateral regions 8a, 8b flanking where the input waveguide 1 abuts to the slab-like waveguide 3 are subject to a relatively low radiation intensity in comparison to other regions of the slab-like waveguide 3. The inventor has also appreciated that radiation spreading outwardly into the waveguide 3 as illustrated is not precisely bounded as it diverges in the slab-like waveguide 3 away from the input waveguide 1. Indeed, the inventor has appreciated that it is preferable to shape the slab-like waveguide 3 into a flared region where it abuts onto the input waveguide 1. Such a flared region according to the invention provides a precise boundary for radiation diverging from the input waveguide 1 and thereby makes the performance of the single mode coupler more predictable and controlled.

Referring now to Figure 2, there is shown a schematic diagram of a known optical device coupler is described in the European patent no. EP 0 563 084 B1, the device coupler being indicated generally by 10. The device coupler 10 is implemented in hollow waveguide technology involving stacking three layers, namely a top layer 12, and intermediate layer 14 and a bottom layer 16. The intermediate layer 14 includes hollow cavity features cut thereinto through which radiation can propagate. The device coupler 10 comprises an input waveguide 18 centrally aligned along an axis 20 and coupled to a first end 22 of a hollow mixing region 24, and two output waveguides 26, 28 connecting to a second end 30 of the mixing region 24, the second end 30 opposite the first end 22.

In operation, fundamental mode radiation propagating along the input waveguide 18 is injected into the mixing region 24 wherein it propagates and interferes to create radiation interference maxima at entrance pupils to the output waveguides 26, 28. The radiation maxima couple relatively efficiently into the output waveguides 26, 28 and corresponding output radiation propagates away from the mixing region along the output waveguides 26, 28.

Although the inventors associated with the European patent EP 0 563 084 B1 have appreciated that the mixing region 24 can be tapered, they have not appreciated benefits that derive from including a flared region between the input waveguide 18 and the mixing region 24 when the mixing region is of substantially rectilinear form, namely where lateral sidewalls and a wall of the second end 30 are mutually orthogonal.

Referring now to Figure 3, there is shown an illustration of a flared optical coupler according to the invention arranged to function as a 1 to 4 way coupler, the flared optical coupler being

indicated generally by 100. The coupler 100 is implemented using rib-waveguide technology in a III-V semiconductor regime. The coupler 100 comprises an input rib waveguide 130, a flared waveguide region 140, a substantially rectilinear mixing waveguide region 150 and four output rib waveguides 160a, 160b, 160c, 160d. The rib waveguides 130, 160a, 160b, 160c, 160d, the flared region 140 and the mixing region 150 are projections in the order of 1 μm high from an exposed surface of a substrate denoted by 120. Moreover, the mixing region 150 includes lateral sidewalls 165a, 165b and an end wall 165c which are substantially mutually orthogonal.

The input waveguide 130 is coupled to a first end of the flared region 140. Likewise, the flared region 140 is coupled at its second end to a first end of the mixing region 150. The output waveguides 160a to 160d are coupled to a second end of the mixing region 150. The input waveguide 130, the flared region 140 and the mixing region 150 are substantially symmetrically disposed about a central axis A-B as shown in Figure 3. Moreover, the output waveguides 160a to 160d are uniformly spatially disposed at the second end of the mixing region 150 as shown.

The flared region 140 is at its first end of substantially similar width to the input waveguide 130. Likewise, the flared region 140 is at its second end of substantially similar width to the mixing region 150. Walls of the flared region 140 subtend an angle θ with respect to the end wall 165c, and an angle $90° - \theta$ with respect to the side walls 165a, 165b. The angle θ is in a range of 30° to 60°. The length of the flared region 140 along the axis A-B will depend upon the length of the mixing region 150 and also upon the angle θ adopted. Where the coupler 100 is employed to couple optical radiation having a free-space wavelength in the order of 1.55 μm, the mixing region 150 conveniently is preferably of a width in a range of 15 μm to 40 μm although other widths are workable. The width and projection height of the input and output waveguides 130, 160a to 160d is chosen to be appropriate to achieve mono-mode wave-guiding at radiation wavelengths of interest.

Operation of the coupler 100 will now be described with reference to Figure 3. Fundamental mode input radiation propagates along the input waveguide 130 to the flared region 140 whereat it diverges as illustrated by arrows and passes to the mixing region 150. In the mixing region 150, the radiation interferes to create a number of spatially disposed maxima and minima as illustrated in the aforementioned US patent US 4 950 045, especially in a manner as illustrated in Figures 2 and 3 of the US patent. At a region corresponding substantially to the end wall 165c, interference maxima are arranged to occur at entrance apertures of the output waveguides 160a to

160d; these maxima are illustrated in a graph indicated by 170 which includes minima such as a minimum 190 and maxima such as a maximum 180. Radiation contributing to the maxima at the entrance apertures is efficiently coupled into the output waveguides 160a to 160d which guide the radiation away from the mixing region 150. Efficient coupling of interference maxima is also exploited in the aforementioned US patent, for example as illustrated in Figure 2 thereof.

The flared region 140 assists to form the maxima at the entrance apertures of the output waveguides 160a to 160d in a more predictable and controlled manner compared to prior art couplers.

Referring now to Figure 4, there is shown an illustration of a flared optical coupler according to the invention arranged to function as a 4 to 1 way coupler, the flared optical coupler being indicated generally by 210. The coupler 210 is implemented using rib-waveguide technology in a III-V semiconductor regime. The coupler 210 comprises an output rib waveguide 230, a flared waveguide region 240, a substantially rectilinear mixing waveguide region 250 and four input rib waveguides 260a, 260b, 260c, 260d. The rib waveguides 230, 260a, 260b, 260c, 260d, the flared region 240 and the mixing region 250 are projections in the order of 1 μm high from an exposed surface of a substrate denoted by 220. Moreover, the mixing region 250 includes lateral sidewalls 265a, 265b and an end wall 265c which are substantially mutually orthogonal.

The output waveguide 230 is coupled to a first end of the flared region 240. Likewise, the flared region 240 is coupled at its second end to a first end of the mixing region 250. The input waveguides 260a to 260d are coupled to a second end of the mixing region 250. The output waveguide 230, the flared region 240 and the mixing region 250 are substantially symmetrically disposed about a central axis C-D as shown in Figure 4. Moreover, the input waveguides 260a to 260d are uniformly spatially disposed at the second end of the mixing region 250 as shown.

The flared region 240 is at its first end of substantially similar width to the output waveguide 230. Likewise, the flared region 240 is at its second end of substantially similar width to the mixing region 250. Walls of the flared region 240 sub-tend an angle β with respect to the end wall 165c, and an angle $90^\circ - \beta$ with respect to the side walls 165a, 165b. The angle β is in a range of 30° to 60°. The length of the flared region 240 along the axis C-D will depend upon the length of the mixing region 250 and also upon the angle β adopted. Where the coupler 210 is employed to couple optical radiation having a free-space wavelength in the order of 1.55 μm, the mixing

region 250 conveniently is preferably of a width in a range of 15 μm to 40 μm although other widths are workable. The width and projection height of the input and output waveguides 230, 260a to 260d is chosen to be appropriate to achieve mono-mode wave-guiding at radiation wavelengths of interest.

Operation of the coupler 210 will now be described with reference to Figure 4. Fundamental mode input radiation propagates along one or more of the input waveguides 260a to 260d to the mixing region 250 whereat the radiation diverges and interferes to create a number of spatially disposed maxima and minima as illustrated in the aforementioned US patent US 4 950 045, especially in a manner as illustrated in Figures 2 and 3 of the US patent. As illustrated by a graph indicated by 270, power maxima arise at exit apertures of the input waveguides 160a to 160d, for example a maximum 280, and elsewhere power minima arise, for example a minimum 290. Assisted by the flared region 240, the radiation forms a maximum at an entrance aperture of the output waveguide 230. Radiation contributing to the maximum at the entrance apertures is tereby efficiently coupled into the output waveguide 230 which guides the radiation away from the flared region 240.

The flared region 240 assists to form the maximum at the entrance aperture of the output waveguide 230 in a more predictable and controlled manner compared to prior art couplers.

The coupler 100 illustrated in Figure 3 can be modified into a 1 to 2 way coupler by only including two output waveguides appropriately positioned where two power maxima occur in the mixing region 150, said maxima occurring due to radiation interference in a manner as described in the aforementioned US patent US 4 950 045. Such a 1 to 2 way coupler can be incorporated into a modulator as shown schematically in Figure 5, the modulator indicated generally by 400.

The Modulator 400 is fabricated using rib waveguide technology onto a substrate denoted by 410. Moreover, the modulator employs III-V semiconductor technology which is susceptible to exhibiting the Pockels effect.

The modulator 400 comprises an input rib waveguide 420, a flared waveguide region 430, a rectilinear mixing waveguide region 440, first and second intermediate waveguides 450a, 450b having associated modulation structures 460a, 460b respectively, an output mixing waveguide region 470, and finally three output waveguides 480a, 480b, 480c. The waveguides 420, 450a,

450b, 480a, 480b, 480c project in the order of 1μm above an exposed surface of the substrate 410 and are operable to guide radiation therealong. The waveguides 420, 450a, 450b, 480a, 480b, 480c each have a width and height as necessary to achieve mono-mode wave guiding at radiation wavelengths of interest.

The flared region 430 has a lateral wall angle of ρ as illustrated, the angle ρ being in a range of 30° to 60° relative to an end wall of the mixing region 440 at which the intermediate waveguides 450a, 450b join.

Operation of the modulator 400 will now be described with reference to Figure 5. Input fundamental mode radiation propagates along the waveguide 420 to the flared region 430 whereat it diverges and passes to the mixing region 440 to interfere therein to generate radiation power maxima at entrance apertures of the intermediate waveguides 450a, 450b. Radiation coupled into the intermediate waveguides 450a, 450b propagates through the structures 460a, 460b respectively onwards to the output mixing region 470. Radiation emitted into the mixing region 470 from the intermediate waveguides 460a, 460b mutually interferes to provide energy maxima at one or more of the output waveguides 480a, 480b, 480b. Formation of the energy maxima is governed by bias potentials M_1, M_2 applied to the structures 460a, 460b respectively which modulates the phase of radiation propagating therethrough by virtue of the Pockels effect in III-V semiconductor layers included within the structures 460a, 460b. Thus, by altering the potentials M_1, M_2, radiation input at the input waveguide 420 can be selectively switched to one or more of the output waveguides 480a, 480b, 480c.

It will be appreciated by one skilled in the art that modifications can be made to the couplers 100, 210 and to the modulator 400 without departing from the scope of the invention. For example, although the couplers 100, 210 are shown having four output waveguides and four input waveguides respectively, it is possible for these couplers to be modified to include two or more such waveguides; as an example the coupler 100 has been modified to become a 1 to 2 coupler in the modulator 400.

Moreover, although the modulators 100, 210 are illustrated in rib waveguide technology, they can alternatively be implemented in other types of waveguide technology, for example in optical fibre waveguide technology.

It will also be appreciated that the flared regions 140, 240 of the couplers 100, 210 respectively act effectively to reduce the presence of residual higher-order radiation modes being coupled to or from the input waveguide 420 and the output waveguide 230 respectively. The flared regions 140, 240 thereby function as spatial filters.

CLAIMS

1. A flared optical coupler comprising an input waveguide, an interference mixing waveguide region and a plurality of output waveguides, the coupler operable to couple radiation from the input waveguide into the mixing region for generating one or more radiation power maxima therein, said one or more maxima for coupling radiation into one or more of the output waveguides, characterised in that the coupler includes a flared waveguide region for coupling between the input waveguide and the mixing region.

2. A coupler according to Claim 1 wherein the flared region has a first aperture coupled to the input waveguide and a second aperture coupled to the mixing region, the first aperture being relatively narrower in width compared to the second aperture.

3. A coupler according to Claim 2 wherein the first aperture is of substantially similar lateral width as the input waveguide and the second aperture is of substantially similar lateral width as the mixing region.

4. A coupler according to Claim 3 wherein peripheral radiation restraining walls of the flared region are substantially linearly flared.

5. A coupler according the Claim 3 or 4 wherein peripheral radiation restraining walls of the flared region are at an angle in a range of 30° to 60° relative to an end radiation restraining wall of the mixing region where the output waveguides join thereonto.

6. A coupler according to Claim 1, 2, 3, 4 or 5 wherein the flared region, the input waveguide and the plurality of output waveguides are implemented in rib-waveguide technology.

7. A coupler according to Claim 6 wherein the rib-waveguide technology is based on a III-V semiconductor material system.

8. A flared optical coupler comprising a plurality of input waveguides, an interference mixing waveguide region and an output waveguide, the coupler operable to couple radiation from one or more of the input waveguides into the mixing region for generating one or more radiation power maxima therein, said one or more maxima for coupling radiation into the output waveguide, characterised in that the coupler includes a flared waveguide region for coupling between the mixing region and the output waveguide.

9. A coupler according to Claim 8 wherein the flared region has a first aperture coupled to the output waveguide and a second aperture coupled to the mixing region, the first aperture being relatively narrower in width compared to the second aperture.

10. A coupler according to Claim 9 wherein the first aperture is of substantially similar lateral width as the output waveguide and the second aperture is of substantially similar lateral width as the mixing region.

11. A coupler according to Claim 10 wherein peripheral radiation restraining walls of the flared region are substantially linearly flared.

12. A coupler according the Claim 10 or 11 wherein peripheral radiation restraining walls of the flared region are at an angle in a range of 30° to 60° relative to an end radiation restraining wall of the mixing region where the input waveguides join thereonto.

13. A coupler according to Claim 8, 9, 10, 11 or 12 wherein the flared region, the output waveguide and the plurality of input waveguides are implemented in rib-waveguide technology.

14. A coupler according to Claim 13 wherein the rib-waveguide technology is based on a III-V semiconductor material system.

15. A coupler substantially as hereinbefore described with reference to one or more of Figures 3 to 5.

16. An electro-optical modulator for selectively diverting input radiation received at the modulator to a plurality of output waveguides, the modulator including:

(a) a coupler according to any one of Claims 1 to 7 for coupling the input radiation into a plurality of intermediate waveguide paths;

(b) modulating means for applying relative phase modulation to radiation propagating along the intermediate waveguides; and

(c) output mixing means for mixing radiation output from the intermediate waveguides and thereby diverting radiation to one or more of the output waveguides in response to one or more modulating signals applied to the modulating means.

17. A modulator according to Claim 16 implemented in rib-waveguide technology.

18. A modulator according to Claim 17 implemented in a III-V semiconductor material system.

19. A modulator according to Claim 16, 17, 18 or 19 wherein the modulating means is operable to exploit the Pockels effect for applying relative phase modulation to radiation propagating along the intermediate waveguides.

20. An electro-optical modulator substantially as hereinbefore described with reference to Figure 5.

The Patent Office

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15

Application No: GB 0024904.5
Claims searched: 1-20

Examiner: Chris Ross
Date of search: 14 February 2001

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.S): G2J(JGDBX)

Int Cl (Ed.7): G02B

Other: Online: WPI, EPODOC, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
EX	EP 1055946 A2	(JDSU) part 54	1, 8 at least
X	EP 0651267 A1	(SEI) Figs 14, 15A, 16-18, 21, 31	"
"	WO 99/59012 A1	(LEVY) Figs 2, 3, 6	"
"	WO 98/39679 A1	(ERICSSON) Figs 2-6	"
"	US 6047096 A	(TLME) Figs 2-6	"
"	US 5689597 A	(USPC) Figs 4, 5	"
"	US 4991926 A	(LS) Fig 5	"
"	JP 090211244 A	(SCCL) abstract, Fig 5	"

X Document indicating lack of novelty or inventive step
Y Document indicating lack of inventive step if combined with one or more other documents of same category.
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A Document indicating technological background and/or state of the art.
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